Some methodological aspects of local advection measurements : a case study

gembloux faculté universitaire des sciences agronomiques

B. Heinesch[1], M. Yernaux[1], M. Aubinet[1]

[1]Biosystems Physics Unit

Gembloux Agricultural University, Avenue de la Faculté 8, B-5030 Gembloux, Belgium, heinesch.b@fsagx.ac.be

Introduction

Assessing the NEE of a forest requires a better understanding of horizontal (F_h) and vertical (F_v) CO_2 advective fluxes. In this study we used [CO_2] measurements performed with a 2D array of sampling points spread throughout the trunk space in conjunction with wind speed measurements to address methodological questions concerning the validity and the representativity of local CO_2 advection evaluation.

Site description

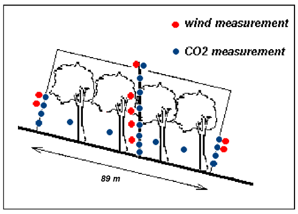
Research is conducted at the Vielsalm experimental site (Belgium; see poster by D. Perrin for details). The uniform slope is of 3%. The two dominant species on the site (27 m tall beech and 35 m tall Douglas fir) are forming two sub-plots, without undercover vegetation, at the interface of which is placed the tower. In stable atmospheric conditions, katabatic flows develop in the trunk space that are decoupled with air motion above the canopy.

Material

- -20 CO_2 sampling points, LICOR 6262, multiplexer with rotating cycle of 200s;
- 2 3D sonic anemometers (Gill R2 and R3)
- 8 2D sonic anemometers (home-made)

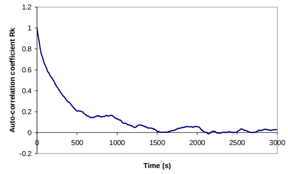
The main data set was obtained during a summer campaign in 2002 (930 katabatic half-hours). The horizontal transect was situated in the Beech sub-plot, along the slope direction.

An additional campaign was made in summer 2003 in the Douglas sub-plot (transect laterally displaced by 50m)



RESULTS

I. Sampling strategy for [CO2]

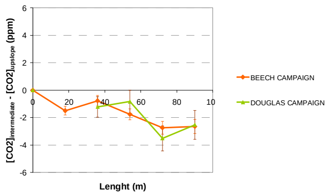


[CO2] autocorrelation function of a high-frequency signal obtained at a fixed point (1m height) during katabatic nights.

The turbulent integral time scale of the perturbations is 300s, giving a spatial extent of 80m (using Taylor hypothesis). In order to follow the perturbation, two samplings at the endpoints of the transect should be separated by an interval between 200 and 500s (time needed by the perturbation to advect).

Simultaneity in measurements is not desirable

II. Spatial representativity of $grad_{CO2,hor}$

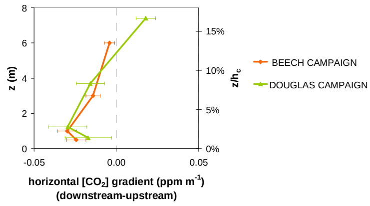


Evolution of the horizontal [CO_2] concentration difference along the horizontal transect (6 sampling points) at 1m above the soil under katabatic conditions.

The total concentration difference of -2.6 ppm is quite uniformly distributed along the transect. The impact of a possible contamination of the horizontal gradient ($grad_{CO2,hor}$) by the vertical one and of very local source heterogeneities is thus limited. The 2 campaigns give similar results despite local differences in CO_2 sources intensity.

The $grad_{CO2,hor}$ is representative at the ecosystem scale.

III. Vertical profile of $grad_{CO2,hor}$

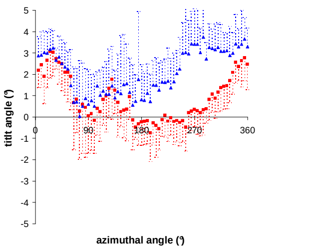


Vertical profile $grad_{CO2,hor}$ under katabatic conditions.

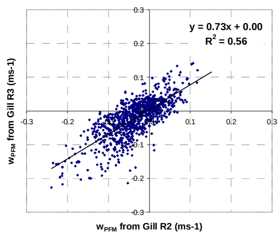
The $grad_{CO2,hor}$ is negative near the soil and falls off to zero at 6m. The depth of the katabatic layer being 20m, it means that only the lowest third of the this layer is relevant to the advection processes.

Only the lowest part of the katabatic layer presents a $grad_{CO2,hor}$.

IV. PFM and sonics intercomparison on w



Relation between second rotation angle and azimutal angle Blue : Gill R2; Red : Gill R3.

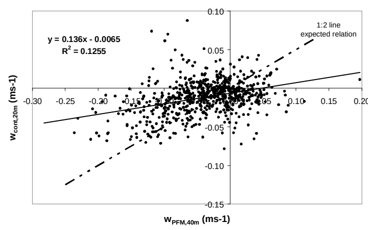


Comparison of corrected vertical velocity for two sonics situated next together (2m) at the top of the main tower (stable conditions).

The Planar Fit Method (PFM) presents an offset of instrumental origin. The departure from the sinusoidal behaviour denotes perturbations of the flow by obstacles. The standard error on the fixed second rotation angle is important (1°). Due to the sensitivity of w on the PFM, it is not surprising that the agreement between the two sonics anemometers is moderate. The resulting uncertainty on F_v is 27%

This comparison reflects the difficulty to obtain accurate w, despite the application of the PFM.

V. Mass balance



Comparison of w obtained by the sonic at the top of the tower and by divergence of u in the trunk space

Continuity equation :

$$\overline{w} = -\frac{\Delta \overline{u}}{\Delta x}\Delta z$$

With

Δx fixed at 89m

Δz chosen at 20m

The w_{cont} obtained with the continuity equation is integrated on the whole transect and is more representative of the real entrainment than the w_{PFM} at the top of the tower, well above the katabatic layer. The w_{cont} at the top of the katabatic layer (20m) is only one fourth of those predicted by a linear vertical profile of w and the direct measurement at the top of the tower.

The mass balance provides lower w (in absolute value) than the PFM.

VI. Entrainment and dilution mechanism

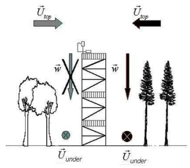
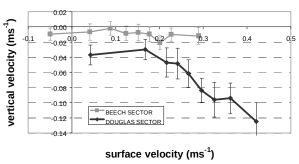
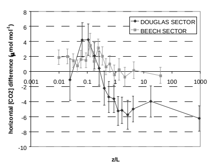


Diagram of air flow pattern according to wind direction above the canopy.



Link between w above the canopy and projected surface velocity for two sectors of above canopy wind direction (stable conditions).

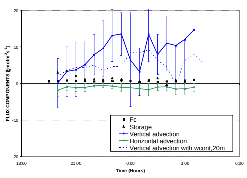


Evolution with stability of horizontal [CO_2] difference at 1m for two sector of wind direction above the canopy.

Katabatic flows along the slope are sometimes associated with a vertical flow from above the canopy down into the trunk space. This incoming air, poor in CO_2, mixes with the horizontal flow and produces a negative $grad_{CO2,hor}$ along the slope (dilution effect). When the entrainment of air is not present, the dilution does not occur. The former case occurs when the wind above the canopy is blowing from the Douglas sector, the latter case when the wind is blowing from the Beech sector. We have no explanation for this difference of air flow pattern between sectors of above wind direction but the impact on the horizontal CO_2 gradient is clear. This result is a strong argument in favour of the reliability of $grad_{CO2,hor}$ and w measurements and of the dilution mechanism.

The occurrence of those katabatic flows does not systematically imply horizontal advection.

VII. CO_2 budget



Night mean course of all fluxes under katabatic conditions

The R_{10} obtained with windy nights is around 3.5 µmolm^{-2}s^{-1}. F_h is negative and very limited. F_v is positive, presents great uncertainties and does not allow the CO_2 balance closure of katabatic nights. The use of w_{cont} reduces the magnitude of F_v and thus improves the budget closure.

The CO_2 balance improves when using w obtained from the continuity equation.

Poster presented at the Carboeurope meeting – Dublin – January 13-17th 2005

Acknowledgements : This work was financially supported by
- European project CARBOEUROFLUX (DGXII, EVK2-CT-1999-00032)
- Fonds national de la recherche scientifique (FNRS)
- Faculté des Sciences Agronomiques de Gembloux.

gembloux faculté universitaire des sciences agronomiques